

# **How Real and Significant is Sorption-Induced Matrix Swelling/Shrinkage in Coalbed Methane and CO<sub>2</sub> Injection Operations**

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## **2005 Research Survey – CO<sub>2</sub>/ECBM (Kuuskraa, 2005)**

**to identify the “... four to five highest priority knowledge gaps of technology barriers that affect the prospects for efficiently storing CO<sub>2</sub> in deep coals and.....challenges posed by the simultaneous recovery of coalbed methane”.**

# Survey Results

## Top Two Issues:

- *swelling of coal and permeability loss due to CO<sub>2</sub> injection*
- *technologies to overcome loss of permeability/injectivity*

# Research – Past and Current

- Matrix shrinkage studies emphasis
- Impact of methane *desorption*-induced matrix shrinkage:

Permeability enhancement

- Matrix swelling studies – few
- *Potential* impact of CO<sub>2</sub> *adsorption*- induced matrix swelling:

Permeability damage

# **Sorption Induced Matrix Volumetric Strain**

- **It is a definite phenomenon and has been measured in the lab by:**

**Moffat and Weale (1955)**

**Reucroft *et al* (1980s)**

**Stefanska *et al* (1990s)**

**Harpalani *et al* (1990s)**

**Seidle *et al* (1990s)**

**Levine *et al* (1990s)**

**Wolf *et al* (2004)**

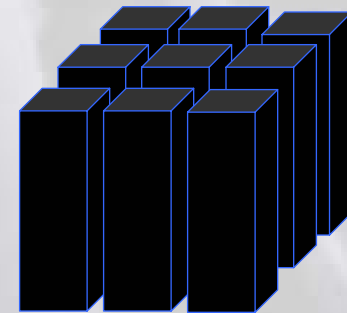
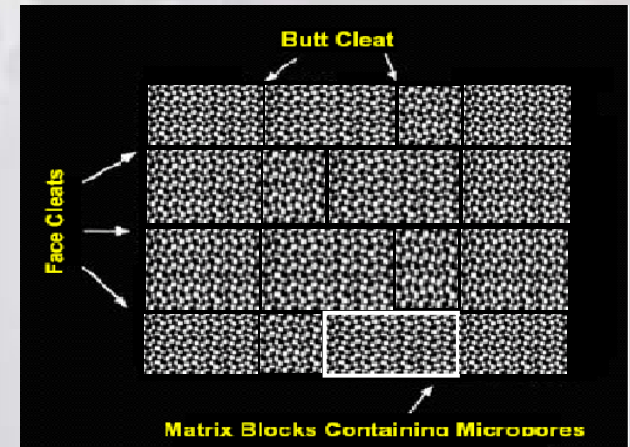
**Keleman (2006)**

# Basis for Impact on Flow

## Release of Methane

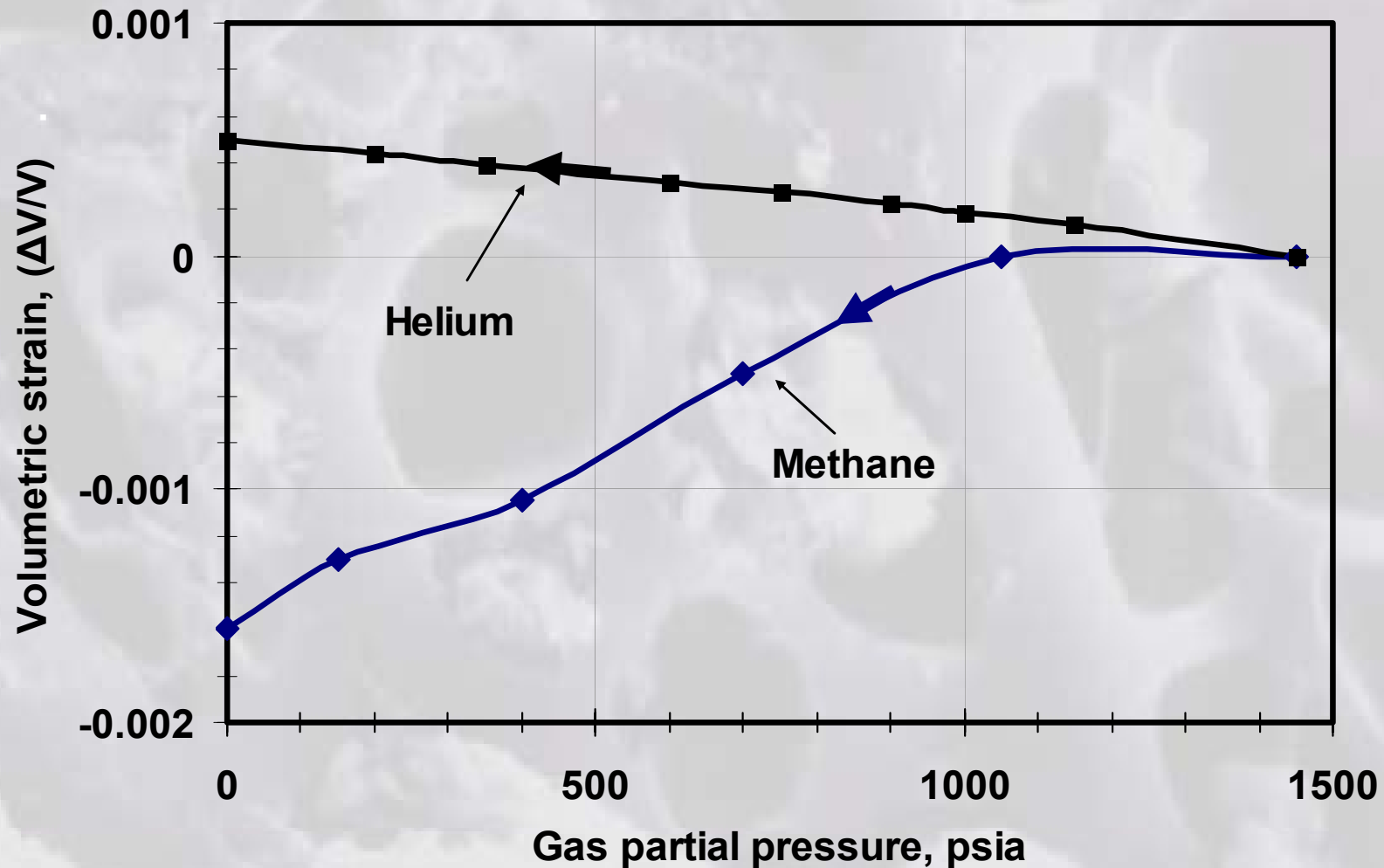
- Change in the volume of coal matrix - associated with desorption
- Change in cleat aperture, and a corresponding
- Change in porosity and permeability

[With “bundle of matchsticks” geometry, flow of gas takes place through the vertical/near vertical cleat system – works very well for San Juan Basin]



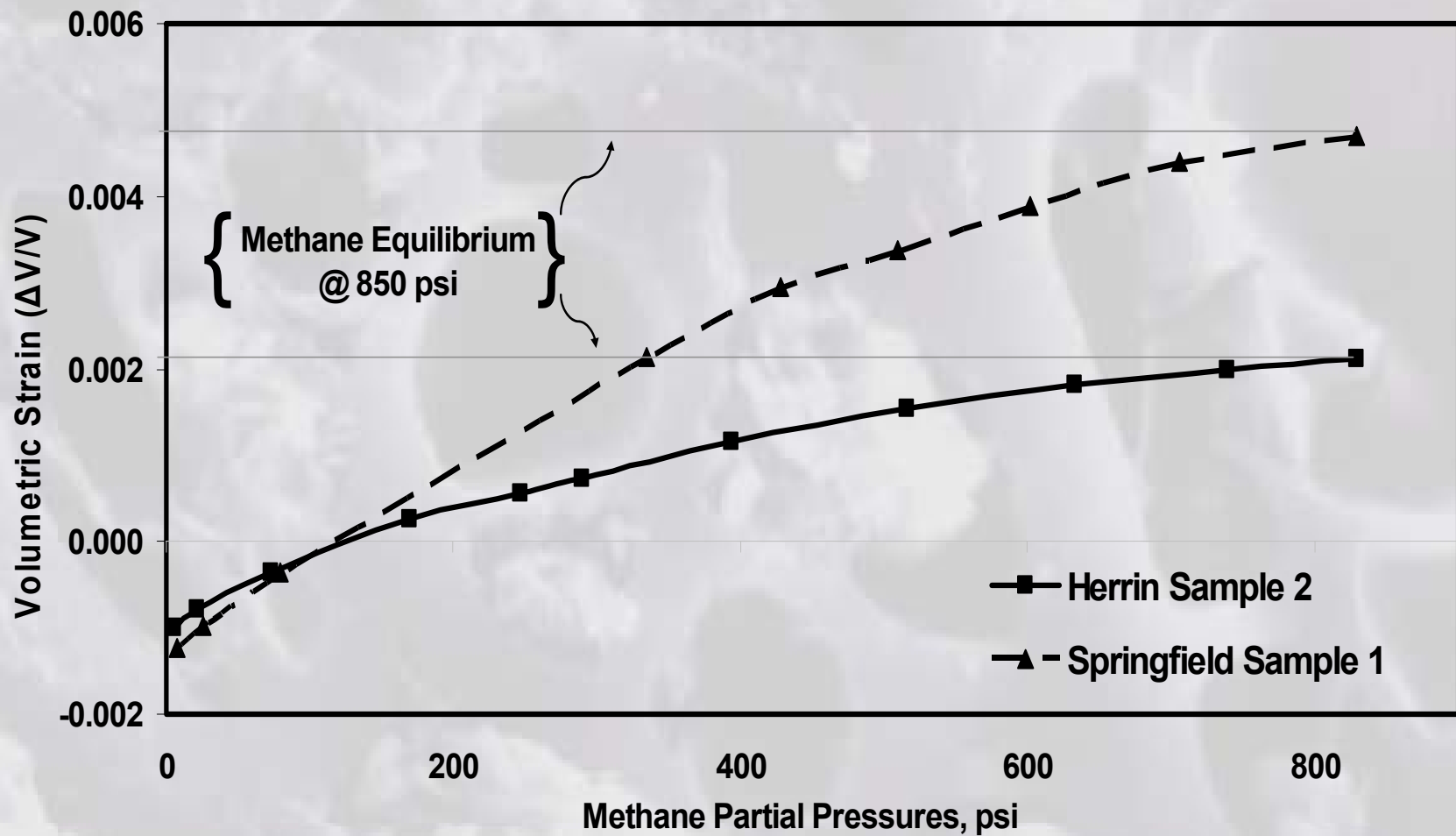
# Volumetric Strain with Changes in Pressure

## Desorption of Methane – San Juan Sample



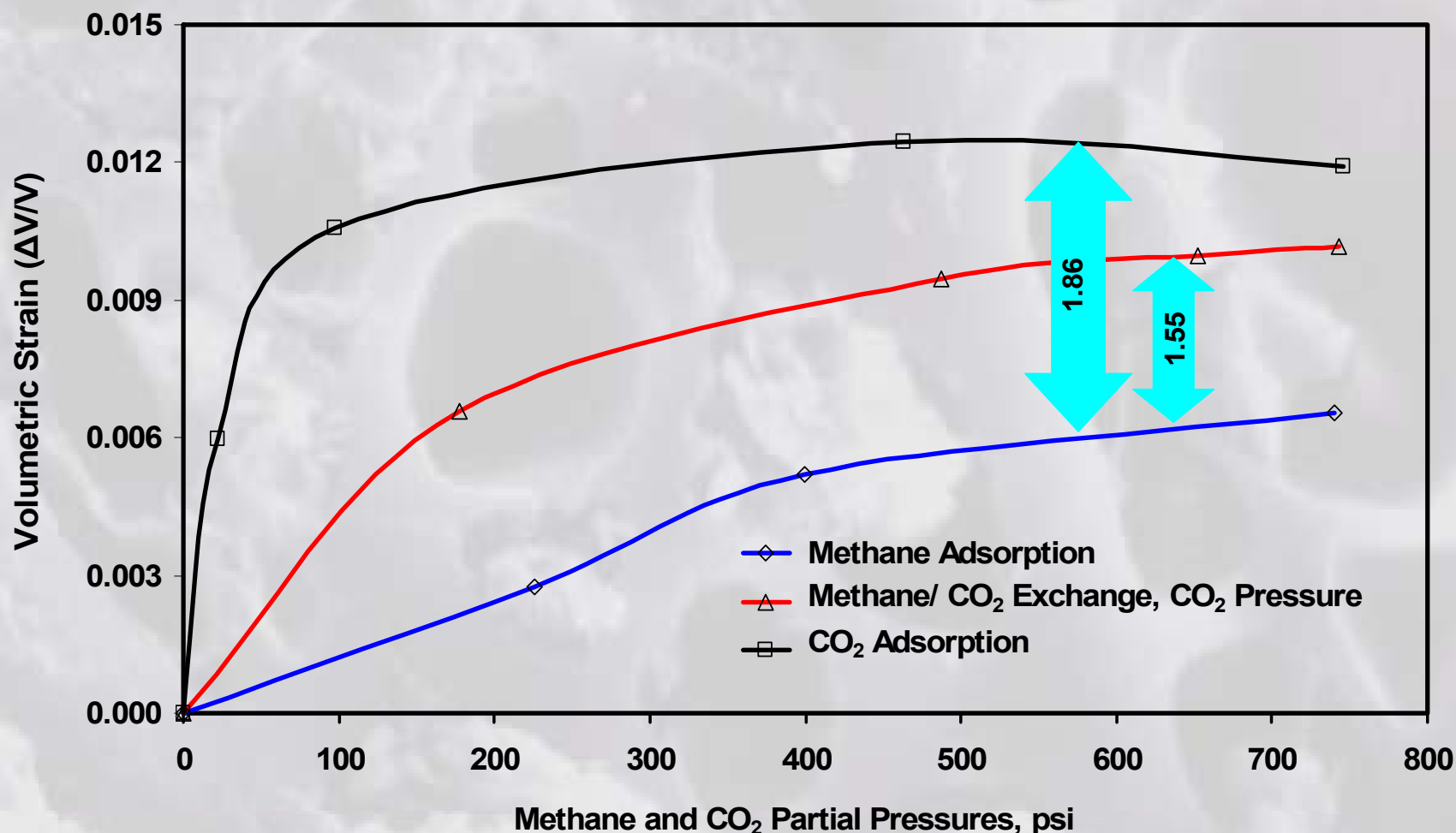
*(Harpalani and Chen, 1997)*

# Volumetric Strain with Desorption of Methane – Illinois Samples

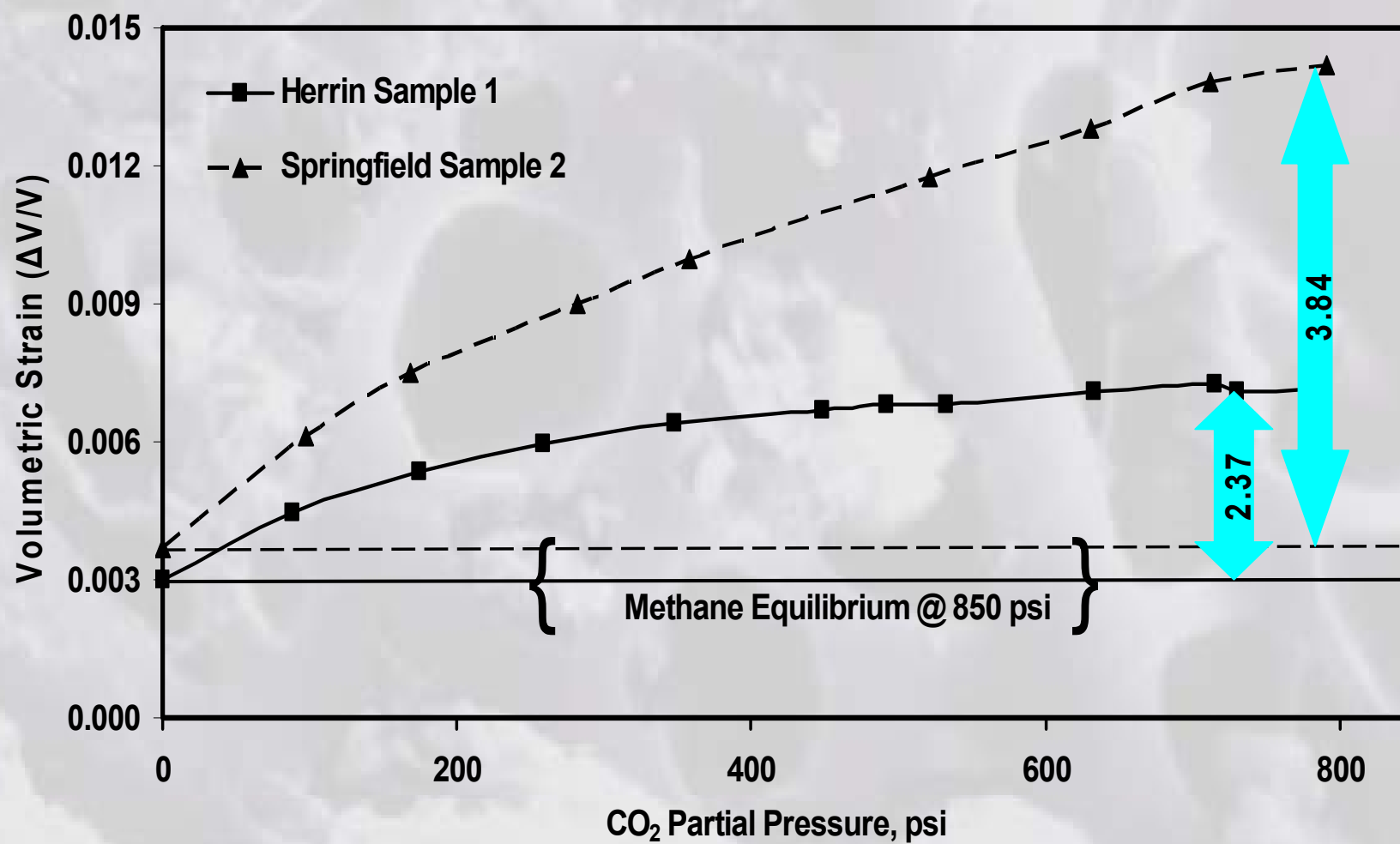




# Volumetric Strain with Increasing Pressure (Adsorption) - San Juan Samples



# Volumetric Strain with Methane/CO<sub>2</sub> Exchange – Illinois Samples



A grayscale microscopic image of coal, showing a complex, porous, and fibrous network of organic material. The texture is highly irregular, with many small voids and interconnected strands.

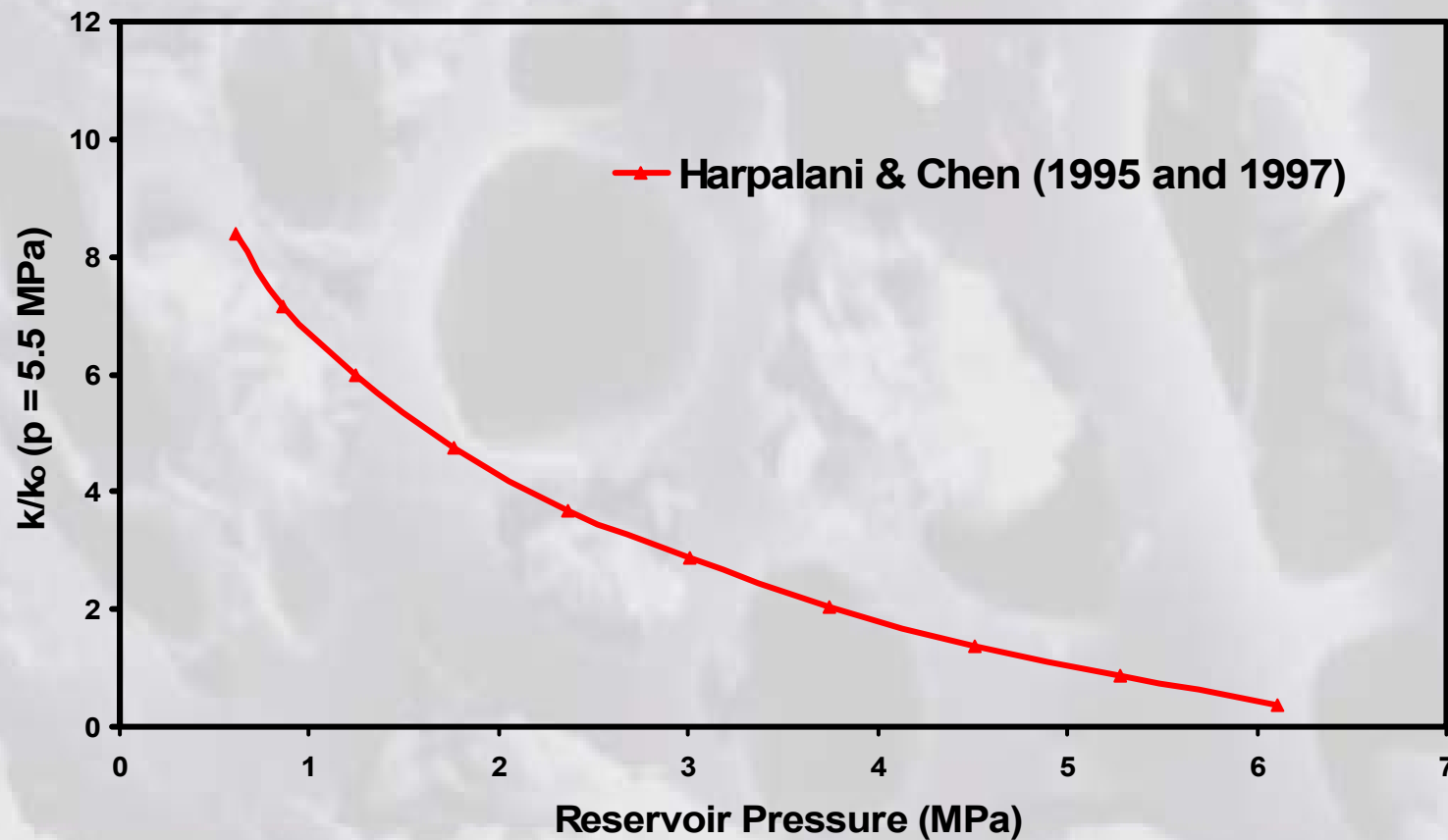
**The effect is real:**

- **ALL coals exhibit shrinkage and swelling when exposed to methane/CO<sub>2</sub>**

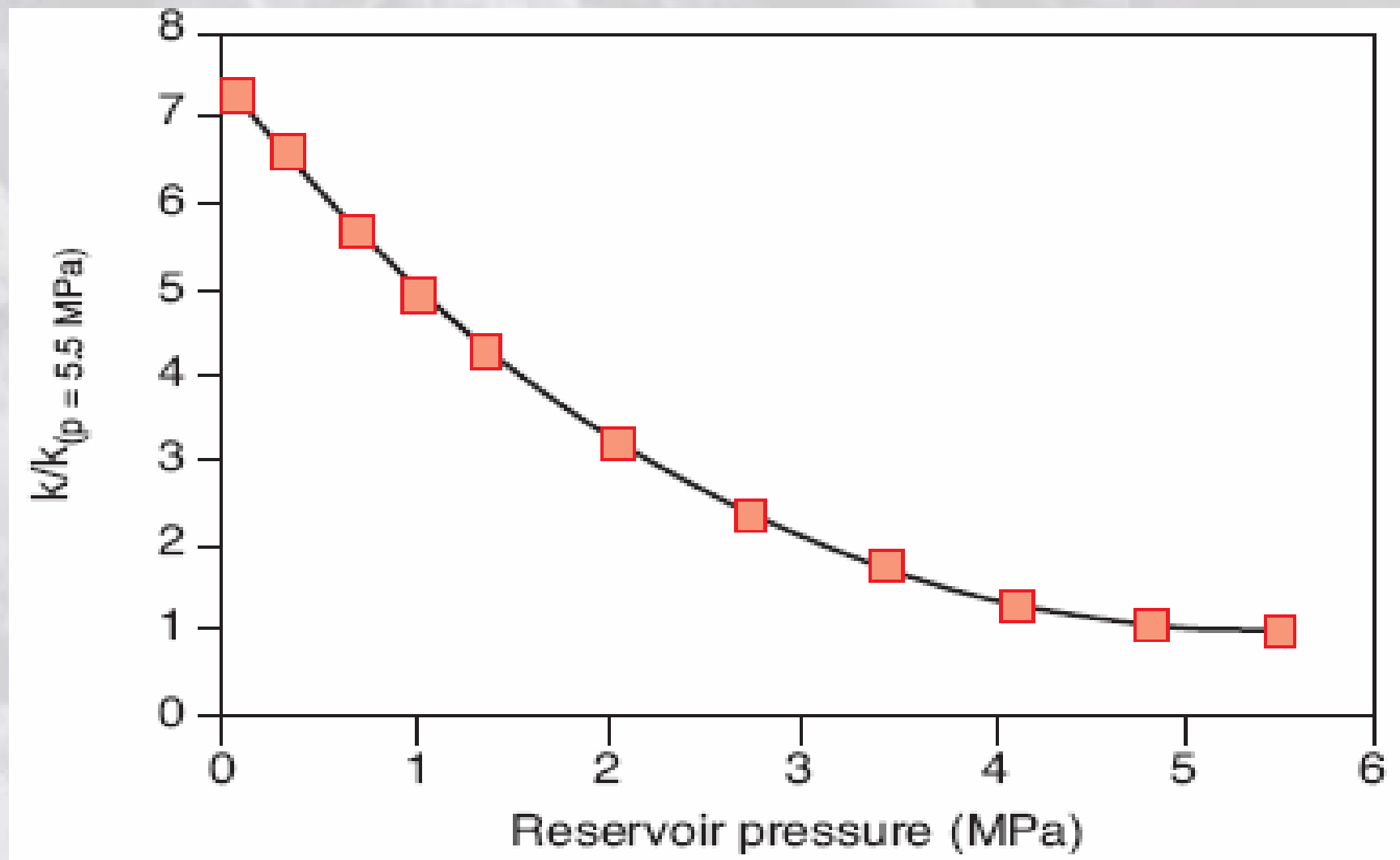
*What about its significance?*

# Permeability Changes with Decrease in Gas Pressure – Lab Measurement

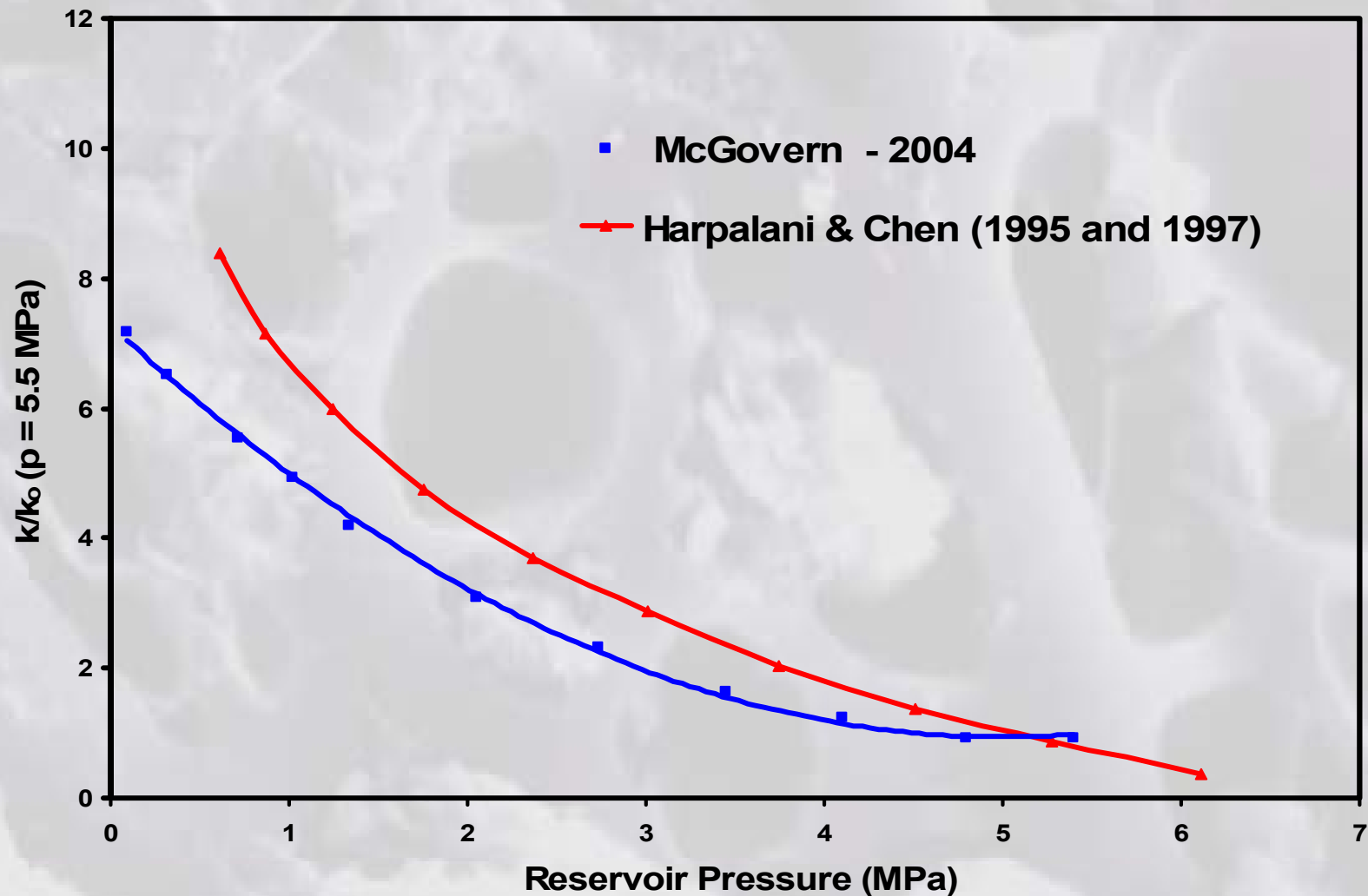
(Harpalani and Chen, 1997)



## Pressure Dependent Permeability Multiplier – Field Results (McGovern, 2004)



# Variation in Permeability with Decrease in Gas Pressure - Comparison of Lab and Field Results



- **Great!! For San Juan Basin**  
**Deep coal – high *in situ* stresses**  
**High gas content**  
**Good permeability**

***What about other Basins (Illinois)?***

***What about with  $CO_2$  injection?***

# **Common Observation and Belief**

**Observation: Injection of CO<sub>2</sub> reduces permeability significantly**

***Allison Unit, New Mexico, US***

***Canada (ARC Project)***

***RECOPOL, Poland***

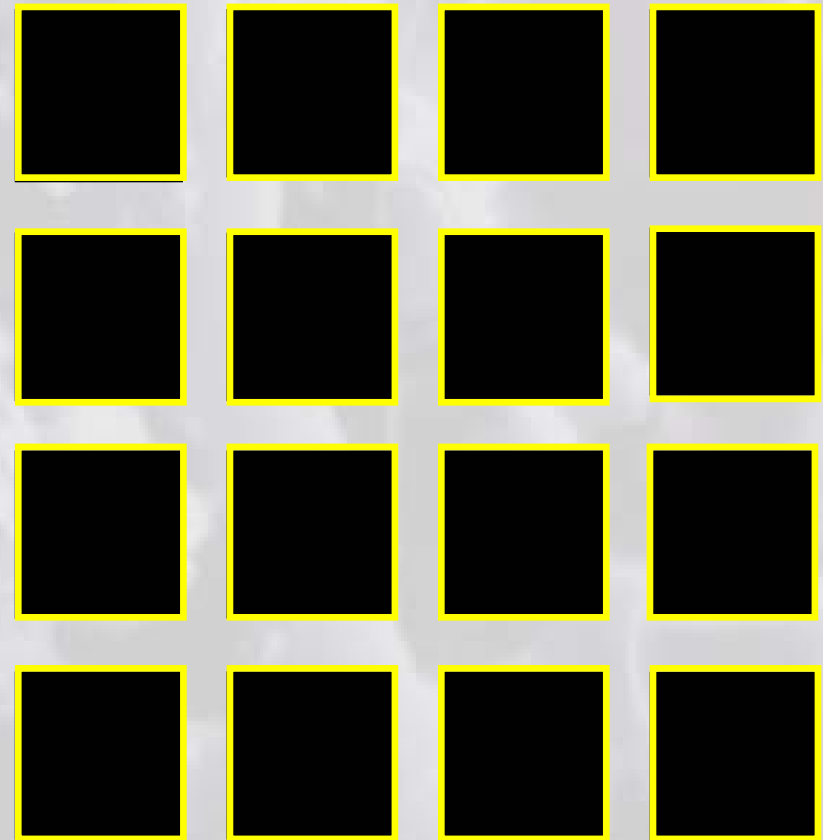
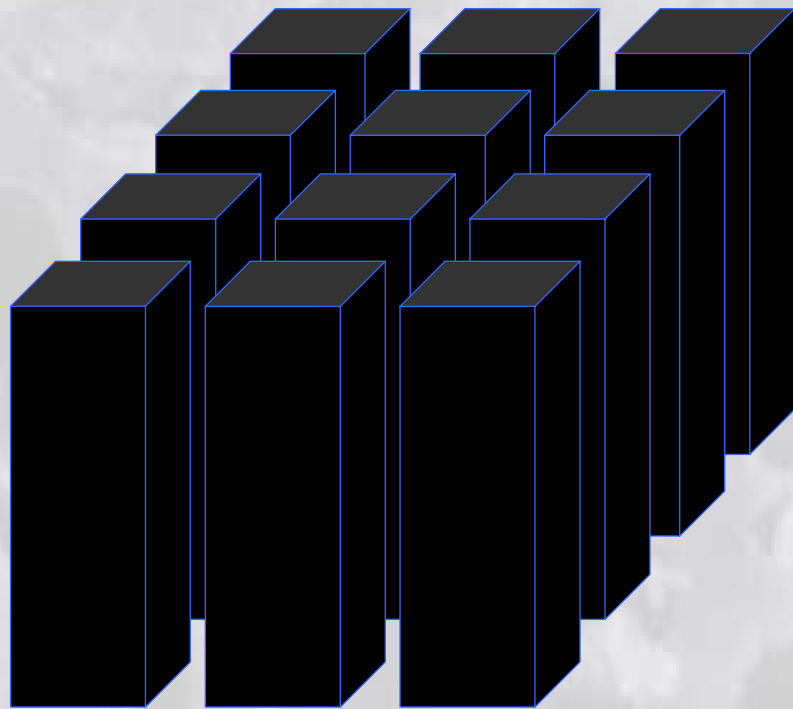
***Hokkaida, Japan – not known***

**Conclusion: Must be due to swelling of coal matrix and closure of cleat aperture**

***After all, matrix swelling is supported by lab measurement of matrix volume when coal is exposed to CO<sub>2</sub>***

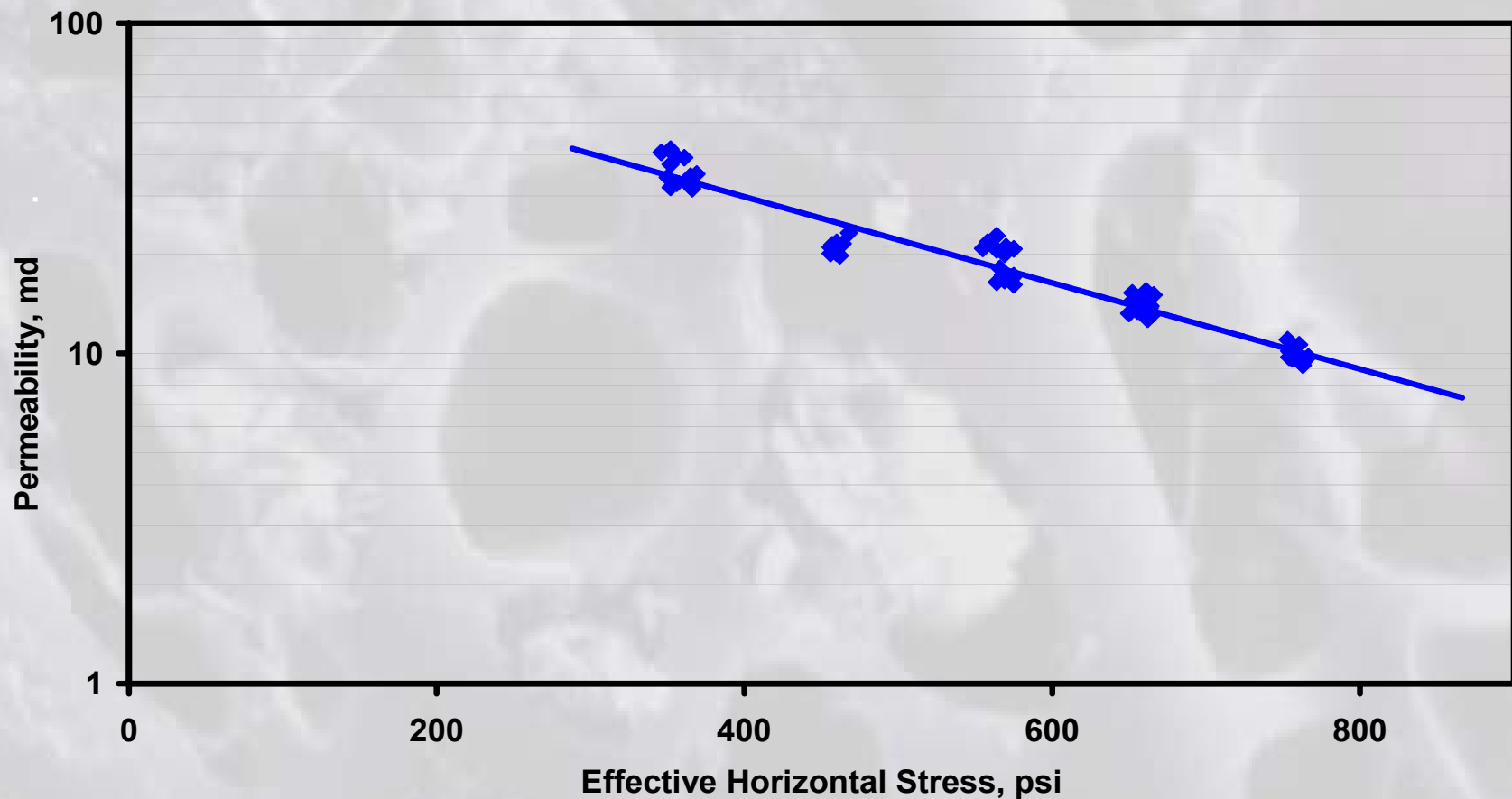


# Change in Cleat Geometry with Change in Matrix Volume (Matchstick Geometry)



■ Swollen Matrix  
□ Initial Matrix

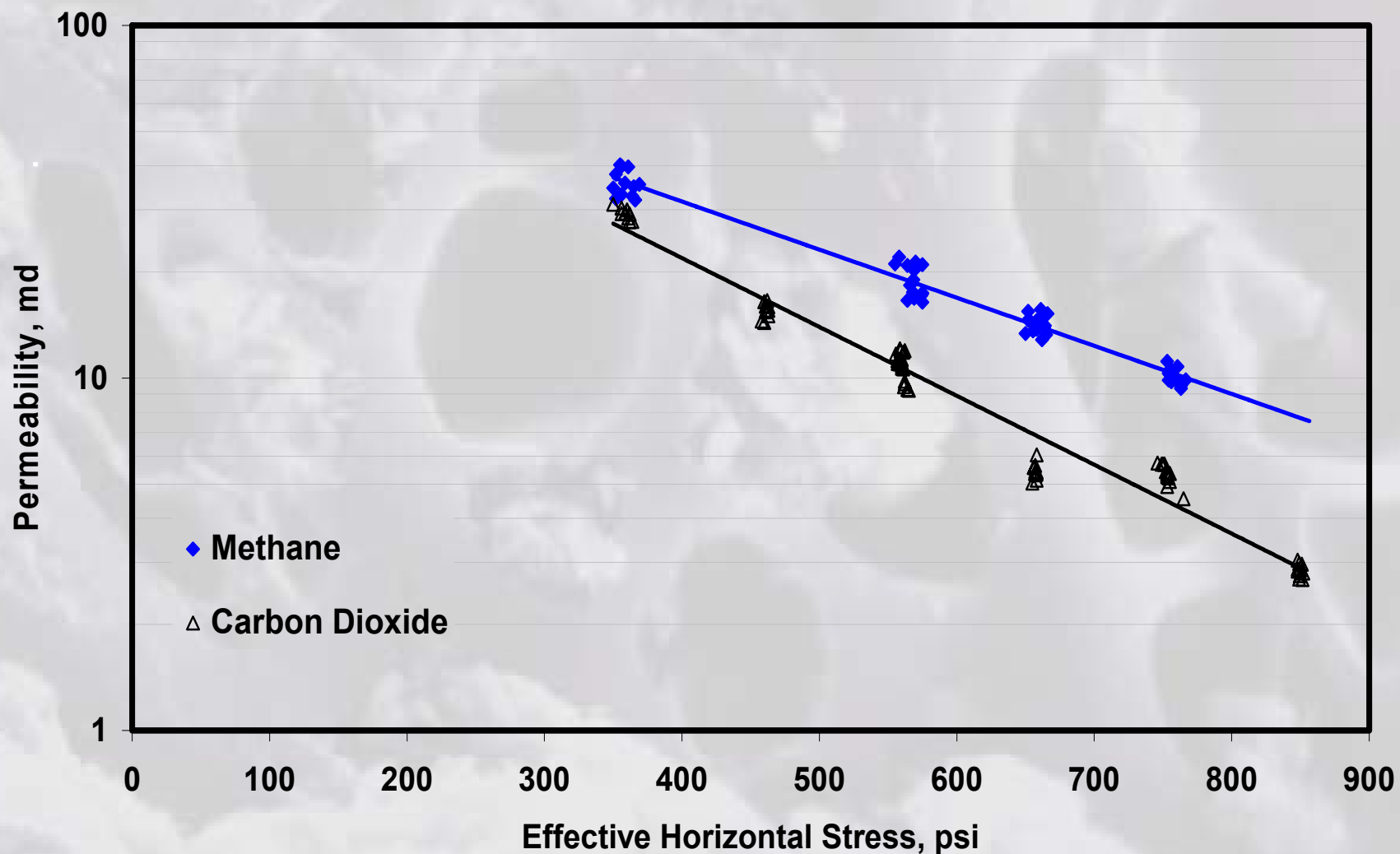
# Permeability Variation with Change in Effective Horizontal Stress



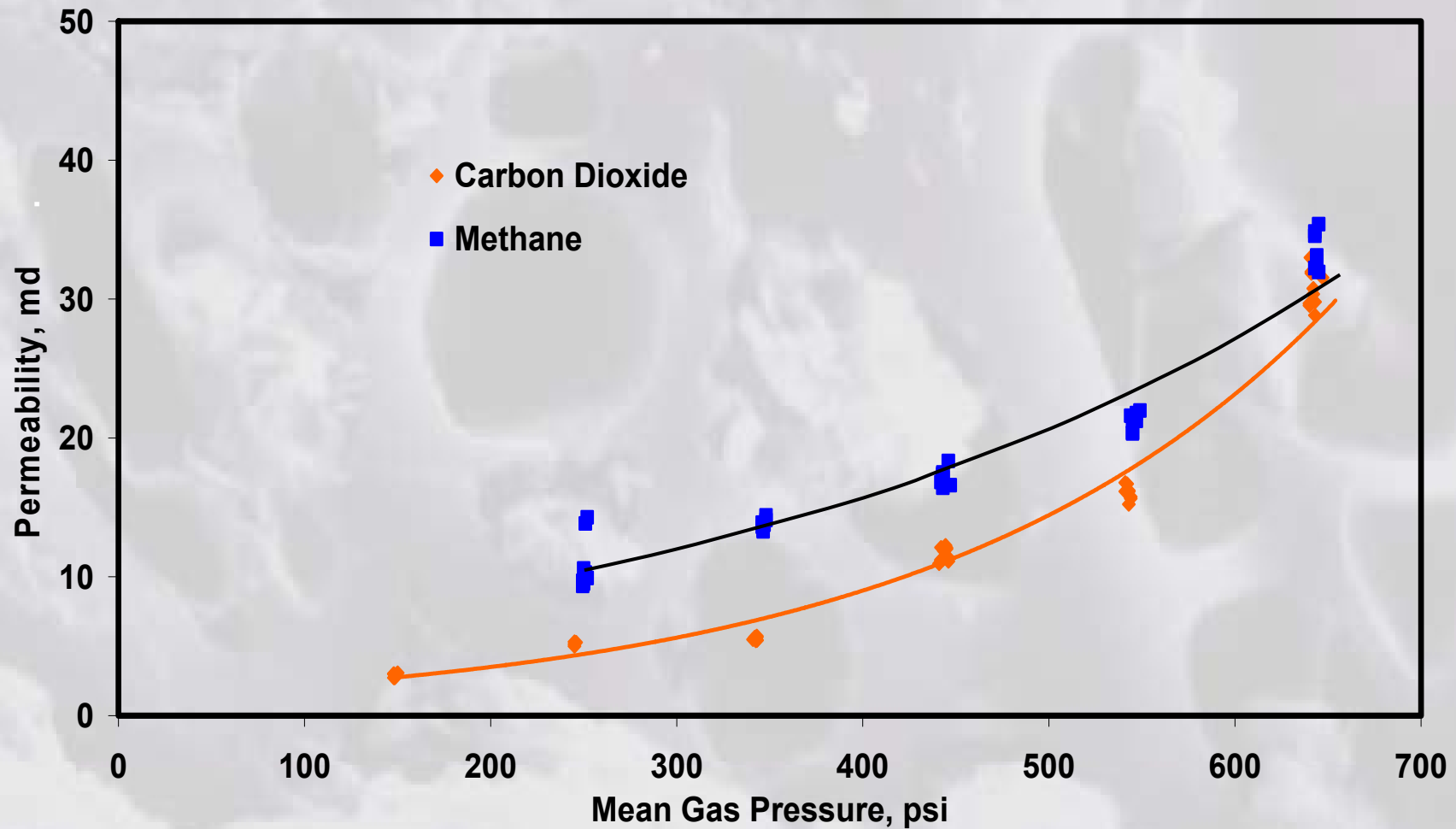
Correlates well with the findings of some of the earlier studies

$$k = Ae^{B\sigma_h}$$

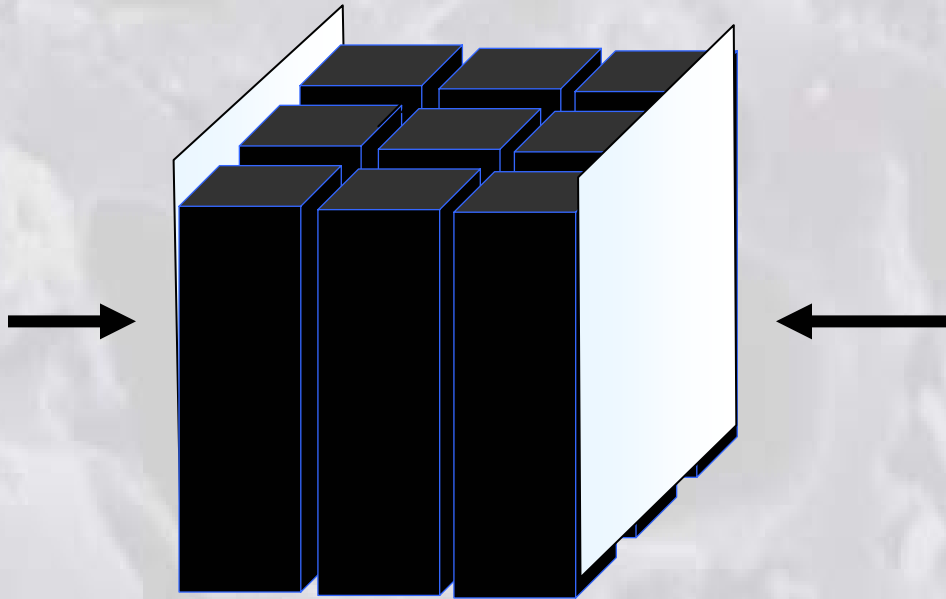
# Permeability Variation with Change in Effective Horizontal Stress



# Variation in Flue Gas and CO<sub>2</sub> Permeability with Changes in Gas Pressure



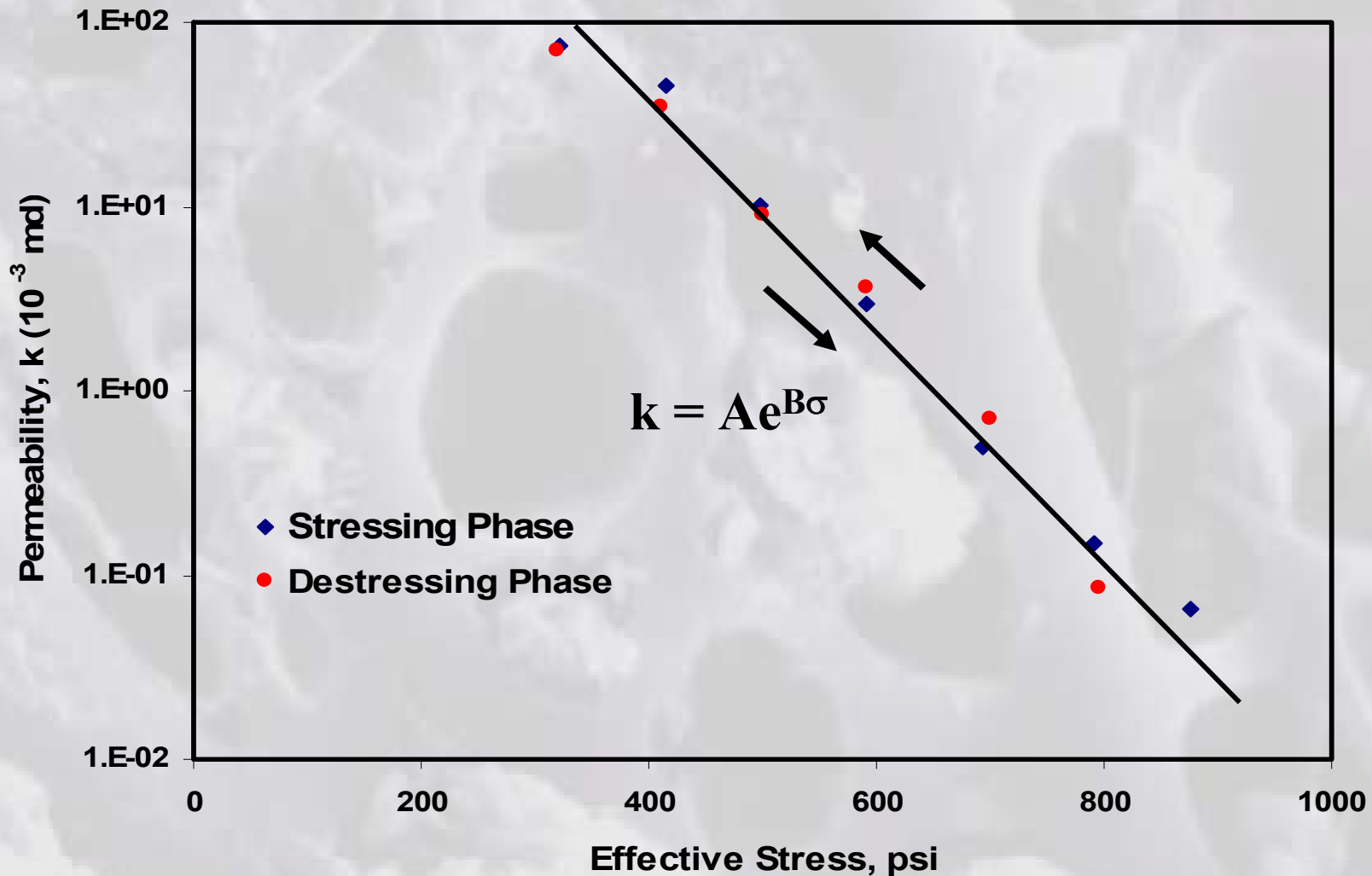
# Coal Matrix Geometry – Bundle of Matchsticks



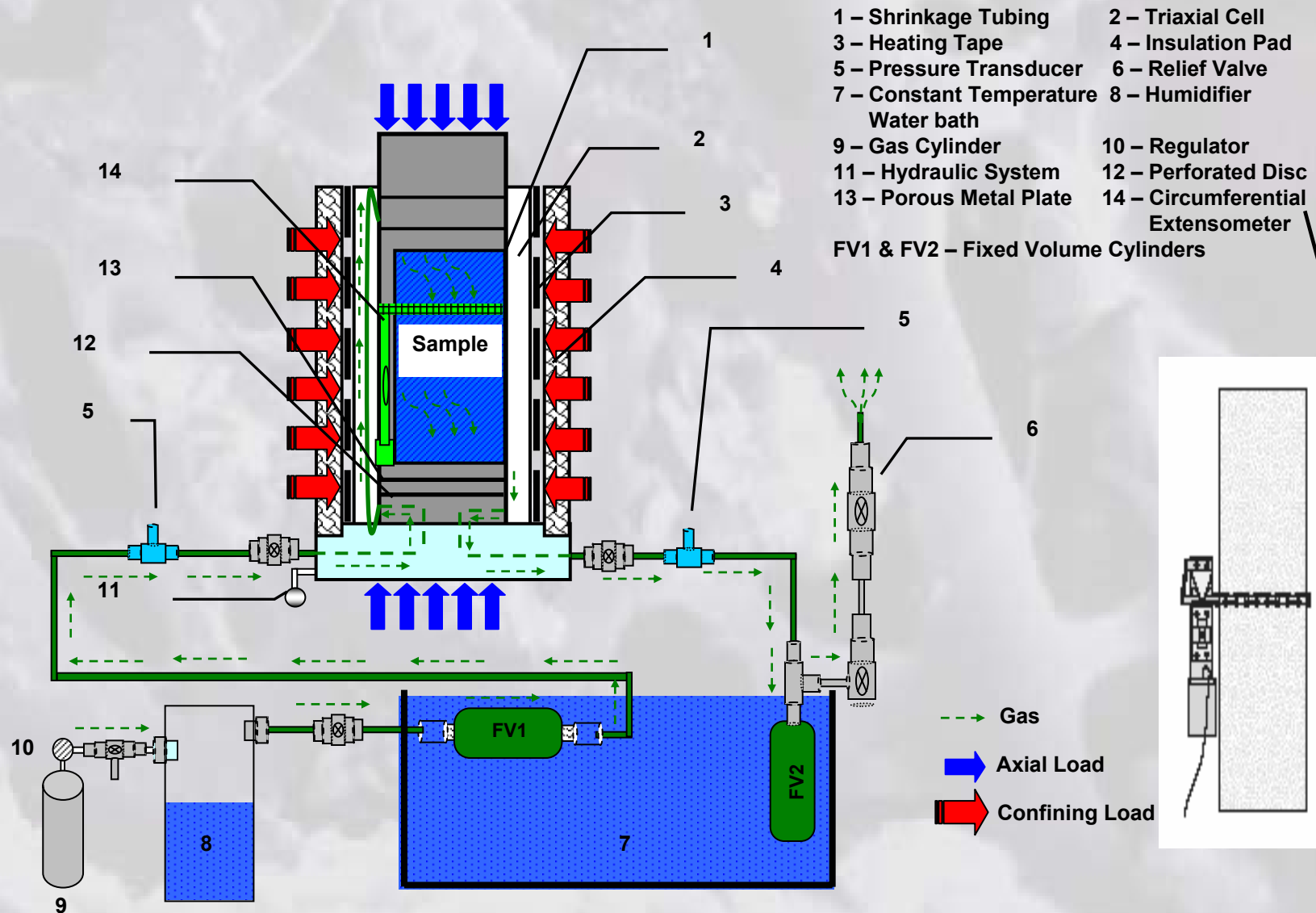
- In actual reservoir conditions, there is lateral confinement.
- The core cannot simply swell.
- As a result, additional stresses are generated.
- Stress-permeability relationship is well established and accepted.
- Determine excess stress by uniaxial strain conditions

# Variation in Permeability with Changes in Effective Stress

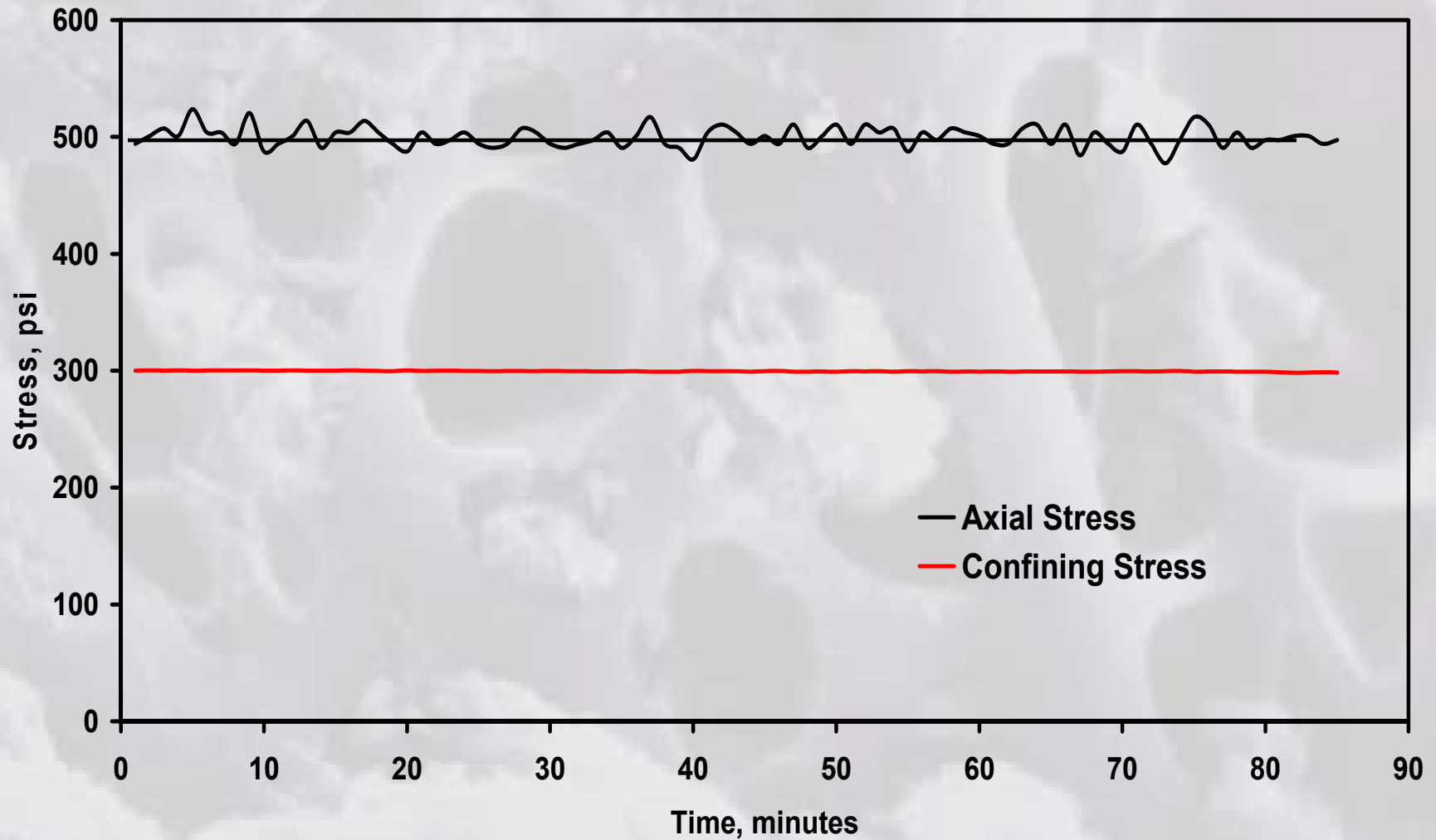
(Somerton *et al*, 1974; Harpalani *et al*, 1985 & 2005; Koenig *et al*, 1988)



# Schematic of Experimental Setup

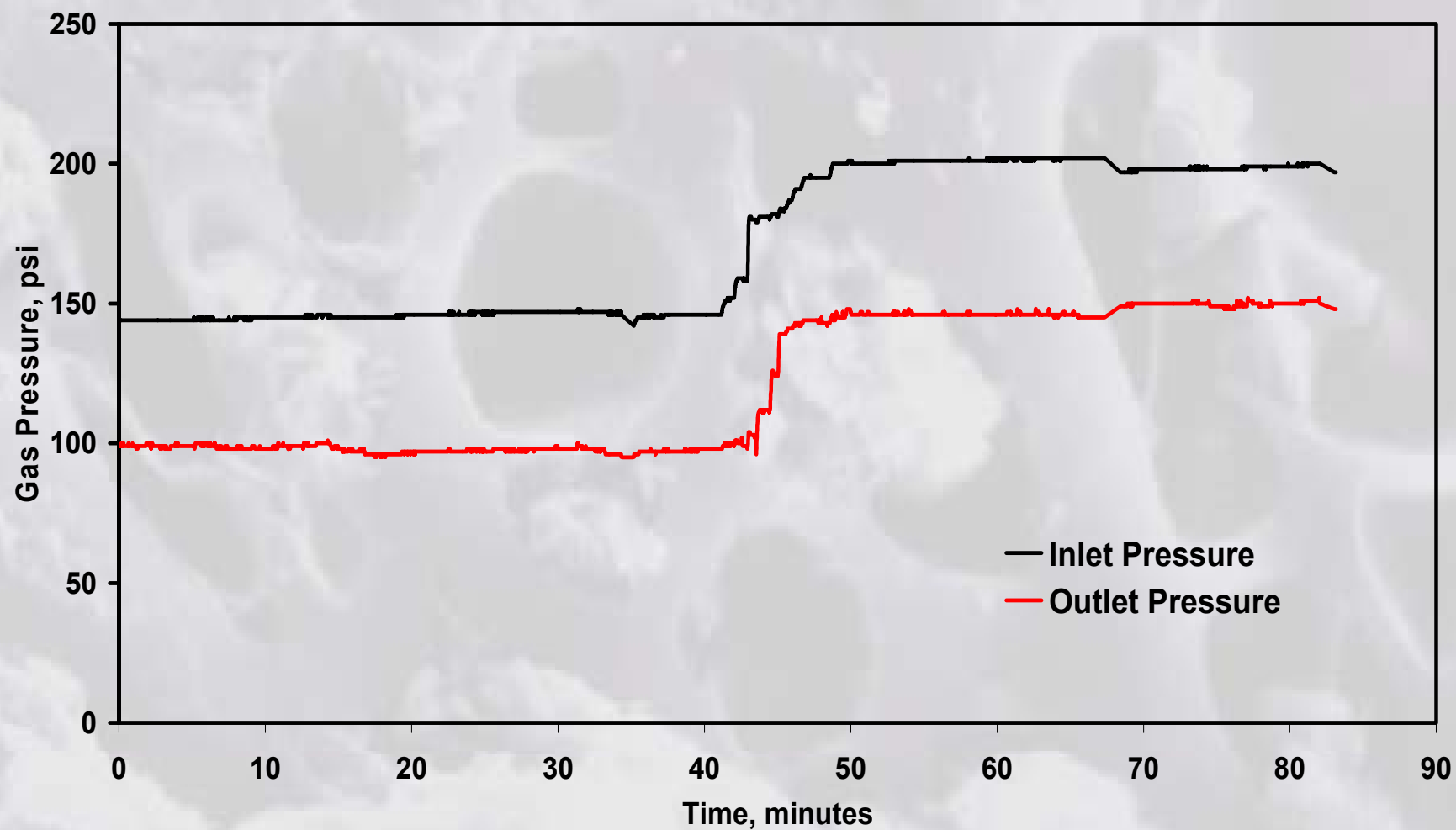


# Variation in Axial and Confining Stress over Time

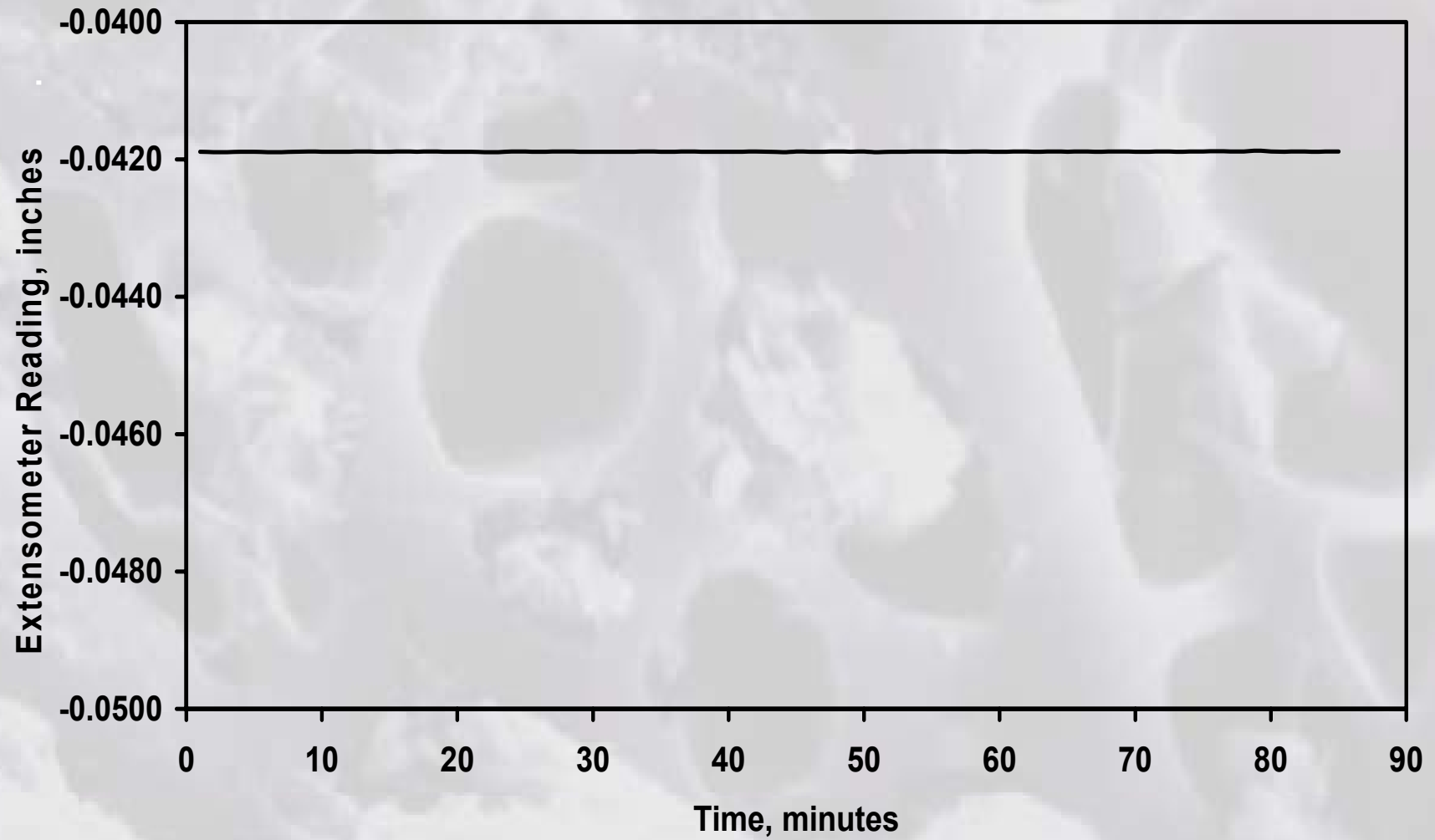




# Variation in Inlet and Outlet Gas Pressure over Time



# Variation in Lateral Strain over Time



## **Summary**

- **CO<sub>2</sub> perm is less than methane perm.**
- **Swelling/shrinkage is probably universal but its impact is not.**
- **Illinois coals do not exhibit perm loss in lab with CO<sub>2</sub> injection, or gain with CBM production.**

## **Future Research Issues – CO<sub>2</sub>/ECBM**

- **Changes in permeability under uniaxial strain\***
- **Excess stress with CO<sub>2</sub> injection\***
- **Counter diffusion with CO<sub>2</sub>/Methane exchange**
- **Plasticization of coal with CO<sub>2</sub> injection**

*\*Currently being pursued*



**Thank you**

**Θυεστιονς???**